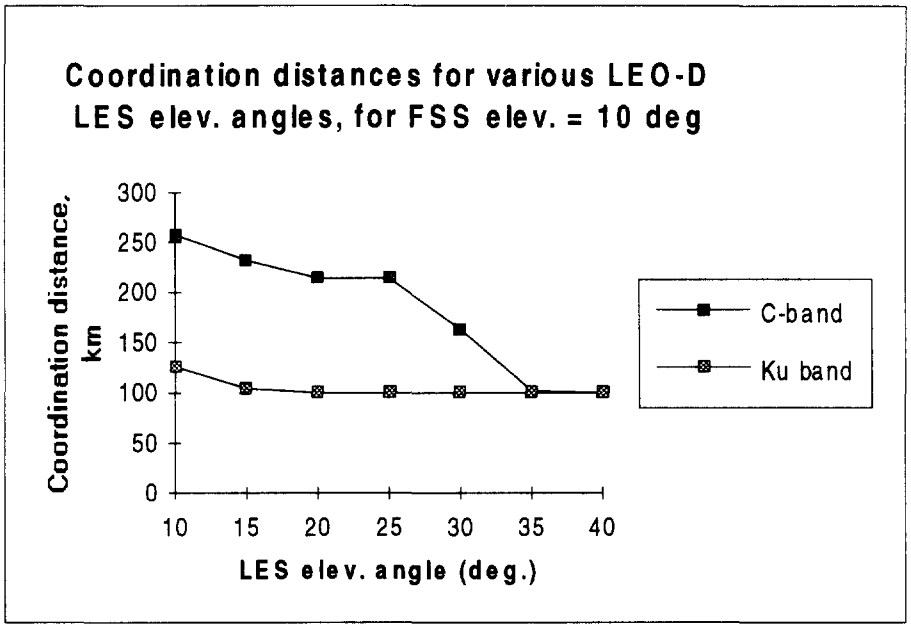
Figure 1: Coordination distance sensitivity to elevation angle



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ATTACHMENT 10

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RTCA TO FAA— Report Your Present Position in the GPS Program

by Dick Arnold, Director, GPS, Communications, Navigation and Surveillance Systems, Federal Aviation Administration

Dave Watrous asked me to give a position report on where we are in the GPS communications, navigation and surveillance program for his readers and to describe my job in the overall FAA GPS/CNS program.

If you've been around aviation a while, you may remember flying in the system before radar. Do you remember the old position report format: "Identification, position, altitude, ETA to next reporting point, and the succeeding reporting point"? What I'll try to do is give you a GPS position report in the old reporting format--there is an older format: Id, position, altitude, airspeed, destination, etc., but I won't press your memory. That one was used, as Dave will remember, before there were reliable landlines.

Identification. First is my identification. About three (3) months ago, the FAA Administrator appointed me to my current position. I've been around Nav and Landing since 1985 from a programmatic standpoint and have been flying precision approaches since 1955 and Radio Range Orientations, Let Downs and Low Approaches before that. Does anyone recall doing a frozen loop orientation, etc.? Oh well, back to business. (page 3)

Air Traffic Management Issues Warm Up In Orlando

Implementing Air Traffic Management—A Systems Approach for the 21st Century proved to be an interesting and informative theme for RTCA's 1993 Symposium. Mr. John A. Burt, Executive Director for System Development, FAA, served as voluntary General Chairman for the event where key people from government and industry segments of aviation — both domestic and international — examined how (page 6)

RTCA TO FAA— Report Your Present Position in the GPS Program

(continued from page 1)

My function is simple--to assume executive responsibility, for the Administrator, to assure that all the diverse elements inside the FAA work together to implement GPS/CNS technology as rapidly and effectively as possible. Additionally, my role is to work with industry and internationally to cooperate in developing the worldwide Global Satellite Navigation System that we all envision.

Position. Where are we right now.

The Department of Defense declared Initial Operating Capability (IOC) in December 1993. In February 1994, David Hinson, the FAA Administrator, stated that the satellite system is an operational and integrated part of the U.S. air traffic control system. What that means is that the DOT/DOD agreed-to specifications for civil use of GPS as published in the Federal Radio Navigation Plan (FRP) will now be adhered to by DOD. Before IOC, those guarantees were not in place as the 24 satellite constellation was in test status. There are still issues concerning the signal specification that need to be worked out with DOD, but we have an interim agreement with them that assures a safe and reliable signal.

Additionally, in February, one manufacturer certified a receiver to perform supplemental en route, terminal and non-precision approach navigation where authorized. This marks the beginning of public use supplemental non-precision approaches. Continental Airlines is already flying, in revenue service, supplemental non-precision approaches under operations specification approval.

One of the questions I most often answer concerns the FAA commitment to install a GPS Wide Area Augmentation System (WAAS). It goes like this, "We thought the FAA was planning to approve Special Category I GPS approaches using local area differential and that we would be flying them shortly. Now, I hear that the FAA is going to develop a Wide Area Augmentation System for GPS that will give us Category I capability. What is the Wide Area System and will it negate Special Category I approaches when it is commissioned? This is causing me some concern because at my airport, we've already made a commitment to install a local area differential GPS."

The answer — which has been, and is being, widely coordinated with industry:

The Wide Area Augmentation System being developed by the FAA will be composed of approximately 24 ground monitors and at least three (3) geostationary satellites. The ground monitors will monitor the health of the satellite system and pass health messages to airborne receivers so that a pilot will affirmatively know when there is a reliable signal and also know when the signal is not useable for navigation. This, as many people know, is called integrity. How does that integrity message get to all aircraft flying in the system? It goes through the three (3) geostationary satellites so that the U.S. is effectively covered by a continuous GPS signal which provides integrity.

Wide Area Augmentation also provides additional satellite availability, which is necessary, because there are certain short periods of time each day when satellite geometry at a given location does not provide enough accuracy (defined in terms of Dilution of Precision or DOP) to provide certain levels of service. In other words, each geostationary satellite will provide an additional satellite ranging signal which will significantly improve geometry and signal availability. Geostationary satellites match earth orbit which means they are apparently stationary over a given point. Because of this characteristic, they can provide additional coverage equivalent to up to six (6) orbiting satellites.

There is a third component to Wide Area which will provide accuracy corrections. This is called Wide Area Differential GPS or WADGPS. The Department of Transportation is negotiating with DOD for approval to provide this accuracy component. If the accuracy component of Wide Area is not approved, then local area differential will be essential for accuracy during approach and landing. Either way, we believe the system will be accurate enough to provide nationwide Category I service. Wide Area would be much less expensive because it would not be necessary for the FAA to do a large procurement for local area systems. Wide Area has the capability to cover every airport in the United States where local could, but would be much more costly.

The FAA has already done extensive research and has proven less than ten meter accuracy and 6.2 second integrity on a test wide area system using a minimum of five (5) ground stations and a test Inmarsat II satellite. Local Area testing, in a research environment, has produced very near Category I accuracy and separate testing with miniature pseudolites has produced consistently repeatable sub two centimeter accuracy with equivalent integrity.

The latter tests are the beginning of Category III testing, which will be fully underway later this year upon the award of a competitive contract for determination of Category III capability with GPS.

Wide Area Augmentation Specifications are completed, the system has been designed and the FAA will now begin the process to procure the system.

This is our present position.

Altitude. Following our position report format--the above accuracies have been produced in the vertical plane as well as even more precisely in the horizontal.

ETA to next reporting point. The schedule for Wide Area implementation is targeted to having an operational Wide Area Augmentation System in place at the end of 1996.

We believe that private operators under special approval will be flying local area Special Category I approaches this year. We believe privately established Local Area Differential Systems will proliferate rapidly and provide service to multiple runways at a given airport and at adjacent airports within twenty miles.

Succeeding Reporting Point. There are several important events on the horizon. There is a very significant ICAO Com/Div meeting coming up in March of 1995 when future approach architectures will be debated among nations and changes in the current ICAO approach and landing policies may be implemented. The Category III GPS studies will play a significant role in determining the U.S. position at that meeting.

After a robust Wide Area System is in place, the evolution from ground-based navaids will take place. The FAA has committed to two-way satellite communications in the Pacific. That, combined with satellite navigation, will be the harbinger of reduced separation over the oceans.

Key Closing Points

This is our current position in the almost dizzying technical progress of satellite navigation and communication. Key points to close with:

1. The Wide Area Augmentation System is absolutely essential for en route integrity given a 24 satellite constellation. The other method for assuring integrity--Receiver Autonomous Integrity Monitoring (RAIM)--requires six (6) satellites in view with the right geometry. With 24 satellites in orbit, RAIM will not be available approximately 30 percent of the time. During that period of nonavailability, integrity must be supplemented by ground augmentation delivered through the geostationary satellite communications link or the operator will not know the health of the satellite. The FAA is actively exploring ways to improve RAIM availability.

2. One of the main advantages of Wide Area is that a precision approach capability will be available at many airports that may never have a local system.

3. The augmentation of GPS constellation signals by Wide Area also increases the availability of a robust signal to equal the availability now provided by a single ILS at a given airport.

4. Local Area Differential Systems are essential complements to the Wide Area Augmentation System and will enhance the robustness, safety and redundancy of the total GPS system in this country and will improve individual airport capability. They will do the same worldwide.

5. Not mentioned earlier, but in December 1993, DOD and DOT reached an understanding that allowed for joint management of GPS for civil use. This understanding did not place restraints on the establishment of Local Area Differential Systems and allowed the FAA to move ahead with the integrity and availability of Wide Area Augmentation Systems with the accuracy function to be determined later.

Space prohibits it, but there is more going on. Stay tuned. This is but one position report of many to be given. But the way I forgot to give you our current airspeed in trying to stay with the rapidly progressing state of the art--above Mach One. Couldn't fly that fast down the light lanes, could we Dave? ■

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ATTACHMENT 11

Why Ka band is unsuitable for accomodating the feederlinks of all MSS applicants

May 2, 1994

The FCC should not rely on Ka band to accomodate the feederlink requirements of all applicants:

1. Wider bandwidth is needed at Ka band because polarization diversity cannot be used.

Ka band feederlinks cannot reuse the frequency spectrum using polarization diversity, as is possible at C band. This is because rain depolarization is severe at Ka band, so that polarization isolation is decreased, leading to cross-talk between copolarized channels on the two polarizations. Thus the frequency needed to accomodate any one MSS applicant's feederlink bandwidth requirement is double that required at lower frequencies.

2. There is not enough bandwidth at Ka band to accomodate 5 MSS applicants, without precluding new users of the band.

This is especially true given the loss of polarization diversity mentioned earlier. New applicants, with new technologies, such as Teledesic, propose to use the Ka band, assuming that they will have no difficulty coordinating with the existing users. If all five MSS applicants use Ka feederlinks, however, this band will not be available for new users. Specifically, the FCC plans to assign the 27.5-30 GHz band to feederlink downlinks. As noted in paragraph 76 of the NPRM, the ACTS satellite already uses the 29-30 GHz band for FSS/MSS demonstration, and that MSS feederlinks and ACTS would cause mutual interference. This leaves only 1.5GHz to be divided among the 5 MSS applicants. If the 3 MSS applicants that have proposed C band feederlinks were to go to Ka band, the bandwidth requirements would be approximately as follows:

Applicant	**Ka band bandwidth needed in each direction (MHz)**
Motorola	100
TRW	100
LQSS	400
Constellation	132
Ellipsat	132

Thus the total bandwidth required by the 5 MSS systems would be 864 MHz. In addition, Teledesic has applied for 400 MHz from 28.6-29 GHz for its service uplinks, and 800 MHz in the 27.6-28.4 GHz range for its feeder uplinks. It is difficult to see how these services could all be accomodated in the 27.5-29 GHz range, let alone new systems that are yet to be proposed.

Similarly, in the 18.1-20.2 GHz band proposed for feederlink downlinks, the 5 MSS applicants would require 864 MHz, and Teledesic would need 1200 MHz, which would leave no room for new systems.

3. It would be difficult to coordinate 5 MSS systems in the Ka band.

The time and effort required on the part of the FCC in order to coordinate 5 MSS systems would be significant, whereas, if some of them are allocated C-band or Ku band frequencies, the amount of coordination needed would be reduced. At C and Ku band, the difficulties involved in coordination would be reduced by the use of Reverse Band Working (RBW), where the feederlinks operate in opposite directions to the FSS links in those bands. However, at Ka band, RBW would be impractical, because of the usage of the 27.5-30 GHz band by the LMDS service. Also RBW would mean that the MSS satellites transmit at 30 GHz, and this is currently beyond the state of the art. Therefore, RBW at Ka band is impractical, leading to greater difficulties in world-wide coordination.

In order to investigate the feasibility of coordination if all 5 MSS applicants used Ka band feederlinks, simulations were performed to determine statistics on the visibility of the other 4 MSS-LEO applicants within the 2 degee half-power beamwidth of a Globalstar gateway. Figures I through III summarize the results.

Figure I gives the probability of a gateway seeing at least one interfering satellite within its 2 degree beamwidth in 2 hours, as a function of gateway latitude. Although these probabilities were calculated based on the first 2 hours, further analysis indicates that statistics over longer periods of time would asymptotically approach finite values slightly less than the ones given here. Although not shown here, there were cases where at least two satellites fell within the 2 degree beamwidth. The probability of 2 satellites being seen by the gateway was about 1/50 th the probability of a single satellite being seen, and it occurred once or twice every hour.

Figure II shows plots of maximum, minimum, average, and standard deviation of the duration of interference for various gateway latitudes. The interference can last as much as 3 minutes in some cases.

Figure III shows statistics of the intervals between consecutive interference occurrences in minutes. It is seen that an interference event can occur every 15 minutes, depending on time and gateway location.

These statistics indicate the difficulty of coordinating 5 MSS systems' feederlinks at Ka band. Note that the simulations did not include the 840 satellites proposed by Teledesic; inclusion of these would lead to significantly greater interference problems.

4. Ka band is not suitable for bent-pipe satellites.

Broad beamwidth feeders are needed to provide the required connectivity for bent-pipe satellites such as the Globalstar satellites. This is because a call may be initiated by a user at one edge of a given satellites's field-of-view, and he may want to be connected to a user (via a gateway) at the other edge of the satellite's field-of-view. Since the satellite does no demodulation or switching, this can only be accomplished by having a global-coverage feederlink antenna on the satellite, so that all gateways seen by the satellite can receive the transmitted signal.

At Ka band high-gain (and therefore narrow-beam) antennas are needed to counter the large rain fades that occur in rainy parts of the world. To provide global coverage would need multiple spot beams on the satellite, tracking the gateways as the satellite moves. Providing high gain tracking antennas at Ka band on the satellite is impractical with phased arrays, because of the low efficiencies of the solid state power amplifiers available at 20-30GHz. This forces the use of tracking dish antennas, of which only 2 or 3 can, practically speaking, be accomodated on the spacesraft. However, in certain regions of the world, such as Europe, as many as 12 gateways may need to be accessed by each satellite (since each country would want its own gateway). This means 12 tracking antennas would be needed on the satellite, whereas only 2 or 3 can be provided, thus significantly reducing the efficiency of the Globalstar system, and increasing the cost of services to the user.

Figure I

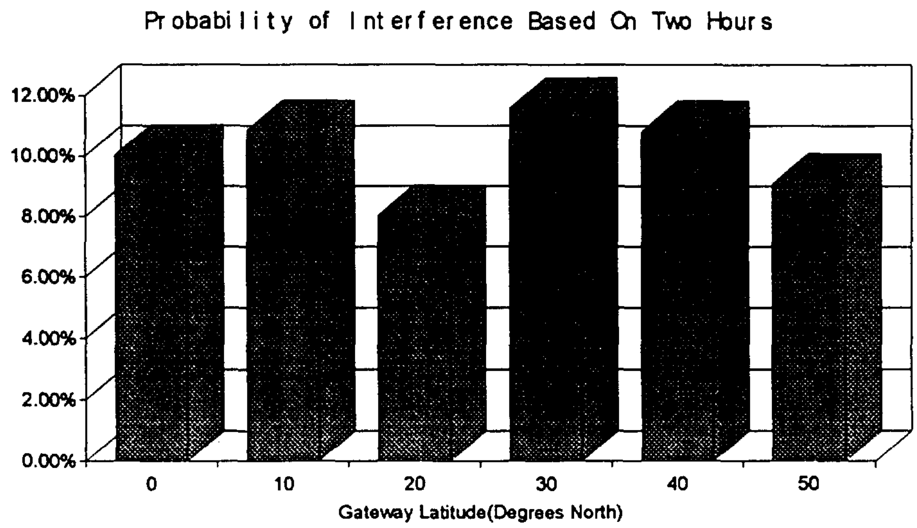


Figure II

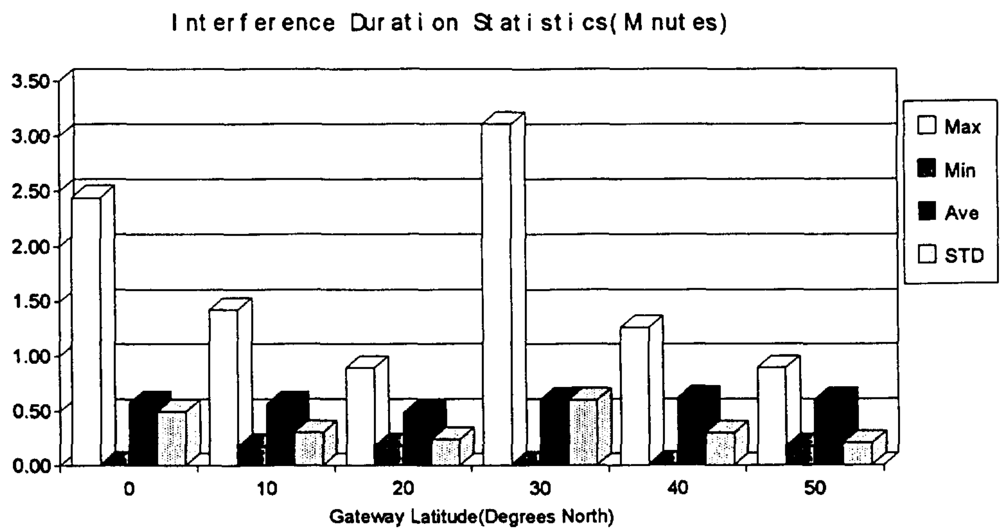
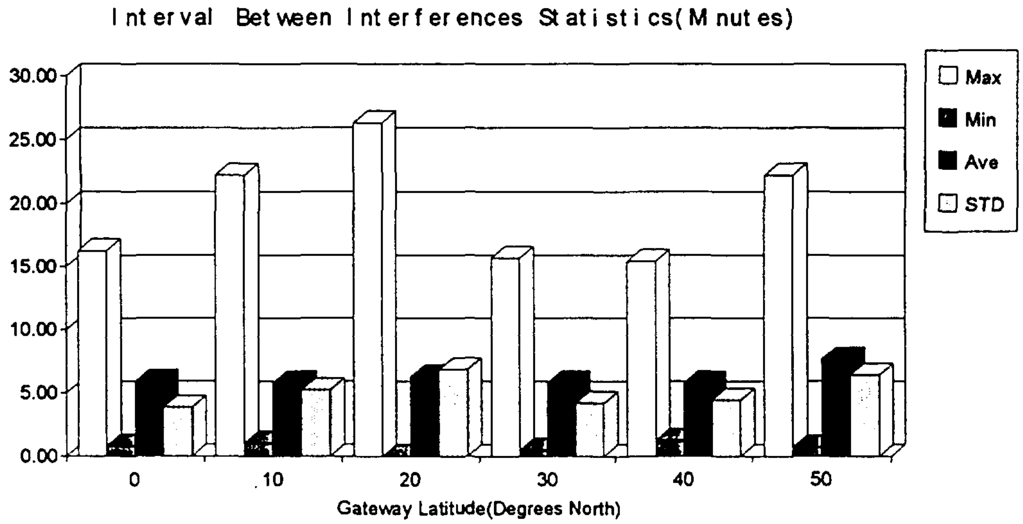


Figure III.


Interval Between Interferences Statistics(Minutes)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
10
20
30
40
50
Gateway Latitude(Degrees North)
Max
Min
Ave
STD